

The University of Chicago

**GOLD ORES OF THE LITTLE
LONG LAC AREA, ONTARIO**

A PART OF A DISSERTATION SUBMITTED TO THE
FACULTY OF THE DIVISION OF THE PHYSICAL
SCIENCES IN CANDIDACY FOR THE DEGREE OF
DOCTOR OF PHILOSOPHY

DEPARTMENT OF GEOLOGY AND PALEONTOLOGY

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HERBERT STOKER ARMSTRONG

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ABSTRACT.

In the Little Long Lac Area gold occurs in two main types of orebodies. The first, exemplified by the Number 2 and Number 30 vein systems at Hard Rock, and the North and West ore zones at MacLeod-Cockshutt, consists of massive sulphide replacement bodies in iron formation. The second consists of silicified zones associated with intrusive acid porphyries, found in the South ore zone at MacLeod-Cockshutt, and in the orebodies at Magnet Consolidated, Bankfield, Tombill, and Jellicoe. Gold-quartz veins associated with acid porphyries, a variety of the second type, are found in the Number 1 vein system at Hard Rock, and the 210 quartz vein at MacLeod-Cockshutt. The orebodies at the Little Long Lac mine are confined to shear zones in arkose, and do not conform to the above general classification.

Hand specimens and polished sections typical of these orebodies have been studied. Composite diagrams representing the mineral paragenesis in each orebody or mine have been drawn up and are discussed in this paper. These eleven diagrams are combined in a table representing a generalization of the mineral relations over the entire area. In addition, the sequence of mineralization is presented in terms of radicles.

From the evidence of mineral sequences, and certain other investigations, it is apparent that the ore deposits of the Little Long Lac area may be correctly placed in Lindgren's upper hypothermal, or lower mesothermal, zone. Possible sources of the ore-depositing solutions are discussed, but no final statement made.

INTRODUCTION.

Location.

THE Little Long Lac area is about 75 miles north of Lake Superior in the Port Arthur mining division of the District of Thunder Bay, Ontario. The area comprises six townships: Houck, McQuesten and Fulford to the north, and Ashmore, Errington and Lindsley to the south of the Port Arthur-Longlac branch of the Canadian National Railway. The seven mines dis-

cussed are distributed through Errington, the western part of Ashmore, and the eastern part of Lindsley townships.

The town of Geraldton, on the railroad, 21 miles west of Long-lac, is a convenient base for operations. Transportation by aeroplane is available. During the summer of 1940, the highway connecting Port Arthur and Geraldton was opened to traffic.

The history of the development of the area has been recorded by E. L. Bruce.¹ The first mine in operation in the region was the Little Long Lac mine, which began production in November, 1934.

General Geography.

Geraldton is at an altitude of 1,110 feet above sea level. The relief is typical of the Canadian Shield: prominent hills or rock ridges are rare and swamps and small lakes are numerous. There are a few larger lakes, but they are relatively shallow. The drainage of this area is sluggish, owing to the proximity of the height of land. Little Long Lac (Kenogamisis lake) drains northeast to James Bay by way of the Kenogami river.

Well-developed esker ridges and other glacial deposits are conspicuous not only from the air, but in aerial photographs as well. The general trend of the ridges is northeast-southwest, but this is by no means constant. As a result of the deposition of a thick mantle of glacial debris, rock outcrops are neither abundant nor extensive.

The marshy areas are characteristically spruce, tamarac, and cedar muskegs, with some cedar and alder swamps. Drier sections have a forest cover of spruce and jackpine, or of poplar and birch. In recent years, forest fires have cut swaths through the region and destroyed much timber which would have been of value in the early stages of mine and prospect development.

Steam was originally the source of power for the early development of the mines in the area. Electrical power is now available from the Nipigon river, 100 miles distant.

¹ Bruce, E. L.: Little Long Lac Gold Area. Ont. Dept. Mines, 44, pt. 3: 3-5, 1935.

GENERAL GEOLOGY.

Stratigraphy.

The stratigraphy of the Little Long Lac area has been outlined by Bruce.² The following discussion is taken from his report, supplemented by personal observations made during the summer of 1940. The table given here is a modification of that of Doctor Bruce.

QUATERNARY

Recent :	Clay, peat.
Pleistocene :	Till, sand, gravel.

Unconformity

PRECAMBRIAN

Quartz diabase dikes.

Intrusive contact

Later Precambrian :	Granite porphyry, feldspar and quartz porphyry dikes.
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Intrusive contact

Diorite, diorite porphyry.

Intrusive contact

"Timiskaming-type" :	Greywacke, arkose, impure quartzite, chlorite schists.
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Iron formation.

Conglomerate.

Unconformity

"Keewatin-type" :	Greenstone, volcanic fragmentals, chlorite schists, and thin beds of black slate.
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"Keewatin-type." Basic volcanics, generally andesitic in composition, constitute most of this series. Subordinate to the lavas

² Ibid., pp. 10-27.

are a few lenses of agglomeratic and tuffaceous rock, and some narrow bands of black slate. Weathering of the andesites shows that they are ellipsoidal or pillow lavas. Other varieties of this rock, in some places coarse-grained, include amygdaloidal and massive greenstones, the latter often associated with ellipsoidal lavas. The coarse grain of the massive greenstones may well cause them to be mistaken for diorite, with which they are identical in chemical and mineralogical composition. Chlorite schists commonly result from the operation of shearing stresses on the basic volcanics.

Observations taken in order to determine the attitude of the volcanics are inconclusive, the outcrops being too widely spaced. The strike of the schistosity is nearly east-west, the dip almost vertical.

"Timiskaming-type." Most of the rocks of this series are extremely varied clastic sediments. Although no definitely basal conglomerate has yet been uncovered, a somewhat continuous conglomeratic member has been found close to the Keewatin greenstone. Most of the conglomeratic beds are lenticular and discontinuous. Pebbles of granite, feldspar porphyry, quartz, chert, and a fine-grained greenstone-like rock have been found in matrices varying from slaty and schistose chloritic to massive fine-grained and quartzose material. No fabric analyses have yet been made on the pebbles although their spherical to ellipsoidal shapes would lend themselves to such investigations. A careful search was made for conglomerate boulders in these conglomerates, but none was found.

Commonest of the rocks of the Timiskaming type are gray, in some places greenish, greywackes of which quartz is the most prominent constituent. As the proportion of feldspar, usually oligoclase, increases, the rocks may better be termed arkosic greywackes or arkoses. Among the commoner accessory minerals, variable in quantity, are amphibole, calcite, chlorite, and magnetite. The east-west shearing in the area has in many places obscured the bedding of these fine-grained sediments. Gradations in grain size, however, are well developed in some places, where

observations have indicated that the tops of the beds are toward the south.

Quantitatively less important than the greywackes, but of considerable interest to students of ore deposits, are the beds of iron formation on which Brant³ made geophysical surveys during the summer of 1939. The extensive outcrops at one locality illustrate the well-banded character: layers of magnetite, hematite, and quartz alternate with bands of red or white fine-grained silica. The richest iron formation bands contain less than 40 per cent of iron, and therefore, at the present time, are not considered to be iron ore. The origin of the iron formation remains an open question.

Fine-grained chlorite schists are interbedded with clastic sediments in some places. Bruce⁴ has examined thin sections of some of these and has interpreted one type as a dike or sill of diorite. He discounts the theory that some of the beds are tuffaceous, and explains the high chlorite content on the basis of a considerable proportion of ferrous iron in the original rock. The recrystallization of such a rock would result in the formation of chlorite.

Later Precambrian. The earlier Precambrian greenstones and sediments have been cut by intrusive rocks of at least three ages.

(i) Diorite and Diorite Porphyry. These dark-colored or speckled rocks form irregular or oval-shaped masses and elongated sill-like lenses. Two large areas, possibly irregular stocks, as well as numerous smaller areas and sills occur in the region. The rock of the stock-like masses has a granitic texture. The variable color of the rock types is a result of considerable variation in the proportion of light to dark minerals. Andesine is the most abundant mineral, even in the darker varieties; the remainder of the rock is made up of dark-green to black amphiboles, quartz, calcite, and chlorite.

Massive diorite is difficult to distinguish from the coarse-

³ Brant, A.: A geophysical and geological survey of the Little Long Lac Area. Ont. Dept. Mines, Prelim. Rep., May, 1940.

⁴ Bruce, E. L.: Op. cit., pp. 15-16.

grained lavas. The discrimination between volcanic or sedimentary chlorite schists and intensely sheared fine-grained diorites which have become chlorite schists is also uncertain.

(ii) Acidic Intrusives. Two types of soda-rich intrusives occur in the area. A soda-granite porphyry mass of unknown shape contains abundant albite and considerable quartz; the remainder comprises orthoclase, apatite, and the secondary minerals calcite, chlorite, epidote, and sericite.

Many small masses and dikes of feldspar and quartz porphyry constitute the second type. Albite is the common phenocryst mineral, but the dike rocks are marked by abundant orthoclase and less quartz than the soda-granite porphyry. Quartz, calcite, sericite, and chlorite are the chief constituents of the ground mass.

The general trend of the dikes, which are themselves sheared, is parallel to the general strike of the country. The dikes cut all the rocks previously mentioned, and although presumably not all precisely contemporaneous, analyses ⁵ suggest that they probably came from a common magmatic source.

(iii) Quartz Diabase. Quartz diabase dikes, usually less than 120 feet wide, are common throughout the area wherever they are not covered by overburden. The general trend of these vertical dikes is north-south. Labradorite and augite crystallize in characteristic ophitic texture; quartz, magnetite and hornblende are primary accessory minerals, chlorite and epidote are secondary.

These dikes are classed as Keweenawan in age by analogy with similar rocks throughout Northern Ontario, particularly those near Lake Nipigon, about 50 miles to the west.

Pleistocene. Unconsolidated gravels, sands, and clays lie unconformably upon the Precambrian rocks. Bruce ⁶ notes the presence of probably pre-Pleistocene weathered zones in some of the prospects. In some places as much as 60 feet of sand and gravel have been found forming irregular knolls and ridges or elongated eskerine deposits. No varved clays have been found in the region.

⁵ Ibid., pp. 21-22.

⁶ Ibid., p. 25.

Recent. Peat and moss deposits are accumulating in the lakes, marshes, and swamps of the present time. Some of the peat deposits have attained notable thicknesses.

Structure.

The structural relations of the volcanic and sedimentary series have been largely obscured by the heavy drift overburden. The direction of strike and amount of dip may be determined from the conglomerate lenses and bands of iron formation, but in the greywackes extreme care must be exercised to distinguish between bedding and shearing. Flat dips to the north or south have been noted, but in general the beds are nearly vertical.

The somewhat continuous band of conglomerate, which has been mentioned previously as outcropping close to the Keewatin greenstone, contains some pebbles which have been derived from the lavas. The sediments are, therefore, younger than the greenstone, and because they lie to the south, the structure may be interpreted as synclinal. This inference is supported by the relations between bedding, schistosity, and the plunge of folds in the iron formation.

Despite the scattered nature of the outcrops, the sediments have proved to be the most amenable to structural investigations. Bruce⁷ has shown that the southern limb of the syncline probably lies well to the south of Little Long Lac, possibly displaced by the granites which are found in that direction. He has traced a gradation southward from the basal conglomerate through a zone of heterogeneous sediments into a wide zone of slaty greywackes.

The gold mines discussed in this paper thus lie within a major syncline which has a westward plunge of about 30°. Steeply dipping, closely folded minor structures complicate the general synclinal structure.

The recognition of faulting is made difficult by the scarcity of outcrops and by the discontinuous character of key members. Strike faulting has probably occurred as evidenced by the strongly developed east-west shear planes. Low angle faults have been

⁷ Ibid., p. 17.

met with in underground developments. In other regions the displacements of diabase dikes serve as a useful indicator of faulting, but here there seems to be little displacement, at least at the surface.

THE ORE DEPOSITS.

The geology and orebodies are described from data available in published reports as well as from information supplied personally by officials of the various mines. The descriptions of the ores are based on the results of examination by the writer of hand specimens and polished sections. The diagrammatic representations of the mineral paragenesis at each mine are composite diagrams compiled from similar tables for individual polished sections and hand specimens. As a general rule, no single specimen will present the complete sequence of any one composite table.

In the following descriptions, the term *bleb* is used in a sense which differs to some extent from the dictionary definition. The definition implies small bubble-shaped or drop-shaped masses. The writer uses the term to signify any very small anhedral mass within another, regardless of whether it be angular or rounded. The term, however, does not include minute regular crystal inclusions such as are found in some sections.

Hard Rock Gold Mines, Limited.

General Geology. The ore deposits at the Hard Rock mine are associated with sediments, porphyry masses, and diabase dikes.

The sediments are greywackes, generally fine-grained and rather dark grey in color. Bedding may be distinct, but in places it is obscured by shearing to such an extent that the rock is more properly termed slate or slaty greywacke. Commonly interbedded with the greywacke are bands of hematite, magnetite, and jasper varying in width from one to six inches and separated by as much as five feet of greywacke. All gradations from this very "light iron formation" to finely laminated "heavy iron formation" are to be observed. The latter consists of bands of greywacke or quartz alternating with magnetite and hematite or jasper. Diamond drill intersections indicate lenses of conglomerate in the

greywacke, in some places exceeding 100 feet in thickness. Close folding and fracturing of these members have resulted in a highly contorted sedimentary series.

Two types of porphyry, both later than the sediments, outcrop on the property and also have been encountered in the underground workings. The basic type outcrops as diorite porphyry and chlorite schist. The difficulty of distinguishing between the latter and volcanic material has been discussed. The larger area of diorite porphyry is probably an irregular boss.

Near the western side of the Hard Rock group of claims, and extending several hundred feet on to the eastern part of the adjacent MacLeod-Cockshutt group, is an irregularly elliptical mass of albitite porphyry. At one time covered with drift and swamp, the mass has been uncovered and now rises as a low hill of light-weathering, pale gray, massive rock cut by veinlets of quartz. The porphyry body is a pipe-like intrusion plunging to the westward at an angle of 30° . Underground development has shown tongues of porphyry extending from both ends of the pipe along bedding and shear planes in the greywacke. The margins have a banded structure as a result of the *lit par lit* mode of emplacement of the porphyry.

Diabase dikes are not numerous. The albitite porphyry pipe is cut by two narrow sub-parallel dikes trending east of north. Similar narrow dikes which do not outcrop have been encountered underground. None of these dikes bears any genetic relation to the ore deposits.

The Orebodies. The orebodies at the Hard Rock mine very closely resemble those at the adjacent MacLeod-Cockshutt with which they are continuous. Three different ore types have been developed, namely, the Number 1, Number 2 and Number 30 vein systems.

The Number 1 system comprises free gold-bearing quartz veins within the albitite porphyry. These veins closely resemble the 210 Quartz Vein at MacLeod-Cockshutt insofar as structural relations are concerned. Certain differences in mineralogy are evident in the high pyrite content of most of the Hard Rock veins.

Only where the quartz is extremely fine is gold found in visible quantities. The veins of this system are not being worked at the present time and no specimens were available.

The Number 2 system differs somewhat from the South Ore Zone at MacLeod-Cockshutt. At both mines the ore is associated with the main albitite porphyry pipe. The difference lies in the fact that at MacLeod-Cockshutt the second associated rock is greywacke, while at Hard Rock it is iron formation. The Number 2 vein system comprises beautifully banded ore, alternate layers of closely folded iron formation having been replaced by sulphides. This banded ore is cut transversely by quartz-tourmaline veinlets which represent fracture fillings with some replacement. No production is being maintained from this system at the present time.

The Number 30 system, or North orebody, is the eastward extension of MacLeod-Cockshutt's North Ore Zone. Like that ore, the Hard Rock ore from this system is a massive sulphide replacement of greywacke bands in iron formation. The structure of the Hard Rock system, however, is not so highly irregular as that of the MacLeod-Cockshutt ore zone. A single vertically-standing large drag-fold apparently relieved the folding stresses which gave rise to the highly complex and irregular structures to the west. The massive sulphide ore is fairly constant across the section of the fold, as also along its western arm. Developed over a stoping length of 850 feet, this orebody produced 97,568 tons of ore, averaging \$8.56 per ton, during the nine months ending September 30, 1941.

Mineral paragenesis (Figs. 1, 2, 3, 7, 11). The mineralogy of the Hard Rock ores is rather simple. Twelve metallic minerals were identified, of which pyrite and arsenopyrite are the most abundant. Free gold was observed in more than half the polished sections examined, but it is not visible in the hand specimens, and none was "high grade."

The following composite tables of paragenesis are compiled for the two main orebodies, the Number 2, and the Number 30 vein systems:

TABLE 1.
NUMBER 2 VEIN SYSTEM.

Pyrite	-----	--
Fracturing	xxx	
Quartz	-----	
Ilmenite (?)		--
Pyrrhotite		----
Sphalerite		----
Chalcopyrite		-----
Cubanite		--
Calcite	-----	
Fracturing		xxx
Pyrite		--
Tourmaline		----
Quartz		-----
Calcite		----
Gold		?----?
Local Faulting		FFF

TABLE 2.
NUMBER 30 VEIN SYSTEM.

Arsenopyrite	-----	
Fracturing	xxx	
Pyrite	-----	
Quartz	-----	--
Local Shearing		vvv
Graphite		-
Pyrrhotite		----
Sphalerite		--
Galena		----
Chalcopyrite		-----
Ilmenite (?)		----
Leucopyrite		--
Fracturing		xxx
Arsenopyrite		----
Calcite (early)		-----
Quartz		-----
Pyrite		-----
Pyrrhotite		----
Gold		-----
Calcite (late)		----

Discussion of the Tables. Table 1. The absence of arsenopyrite is a noteworthy feature of these ores. Although arsenopyrite was not observed in hand specimens or polished sections, it seems very likely that additional sections would reveal its presence, since in this general area arsenopyrite, like pyrite, is almost ubiquitous. Pyrite was the first mineral to crystallize; in the sections available it forms large masses which were cracked during the period of fracturing that followed. The cracks in the pyrite were filled with quartz which carries pyrite conforming

to the quartz. Some pyrite in the sections is conformable to quartz, indicating that where no fracturing has taken place, there is an overlap in the relationship between quartz and pyrite.

The gray mineral identified as ilmenite conforms to and in some places replaces pyrite and quartz. Its relation to the minor sulphides is not clear; smooth and irregular boundaries were observed but no crystal faces of the minor sulphides were found. Ilmenite likely occupies the position indicated in the diagram.

Pyrrhotite, sphalerite and chalcopyrite occur as minute rounded and irregular blebs, occasionally following fractures, in the earlier pyrite grains (Fig. 11). Pyrrhotite and sphalerite have mutual boundaries which have served, in some places, as channels for the infiltration of chalcopyrite which replaces them. In other places chalcopyrite seems to be contemporaneous with sphalerite and pyrrhotite. Cubanite was seen in a single bleb associated with chalcopyrite. Calcite conforms to all the minerals appearing above it in the diagram.

A second period of fracturing is indicated by the presence in one polished section of a vein of quartz and calcite which carries minute euhedra of pyrite. This may be regarded as a third age of pyrite. Black acicular crystals in the quartz veins of the hand specimens are needles of tourmaline which crystallized in part before the quartz but probably later than the pyrite. The fact that some of them conform to crystal outlines of quartz is suggestive of an overlap in the sequence of deposition. A second generation of calcite which occurs in the veinlets is prevailingly later than the second quartz, but in some places mutual boundaries of the two minerals indicate overlap.

The exact position of gold in the sequence is uncertain. It probably was introduced by the quartz-tourmaline vein solutions, but the possibility that it came in with the earlier quartz and minor sulphides should not be overlooked. Gold occurs as irregular blebs in the early pyrite where it fills spaces between the closely set pyrite crystals. It is also found along the contacts of pyrite with the minor sulphides, these contacts apparently having afforded easy access of the gold-bearing solutions.

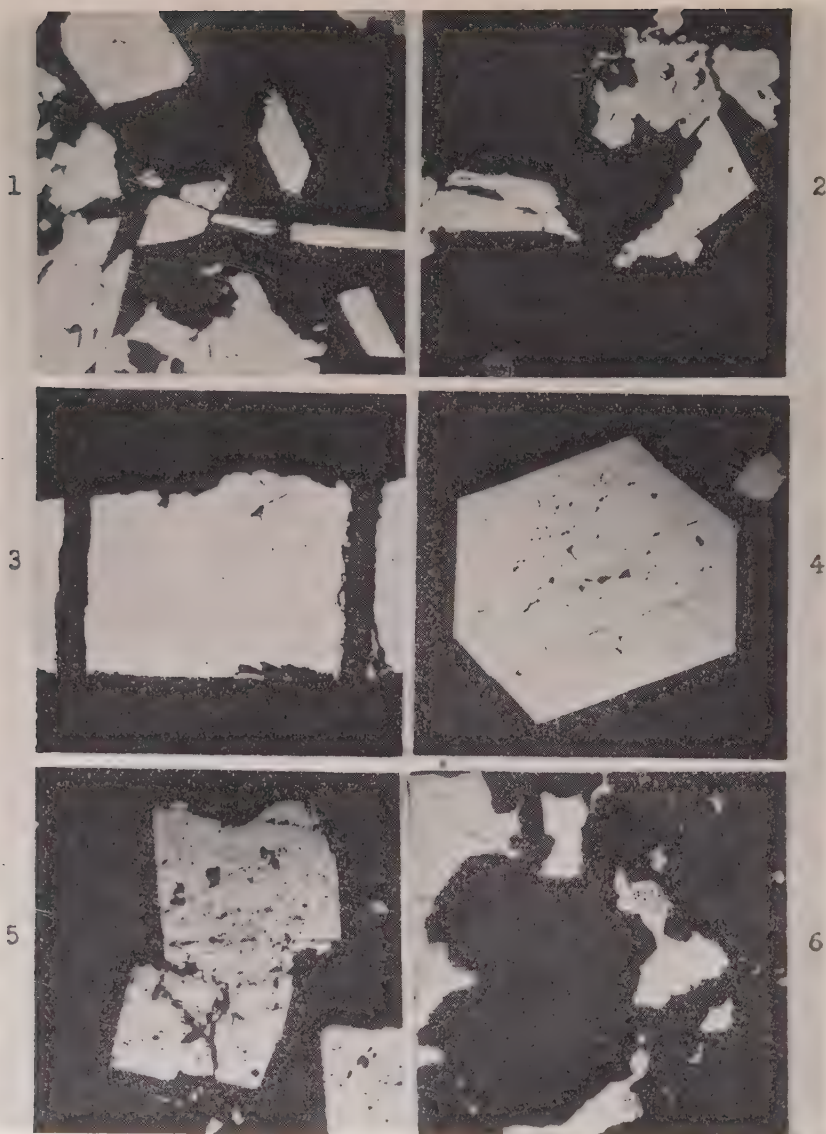


FIG. 1. Diamond- and lath-shaped euhedra of arsenopyrite. Hard Rock Gold Mines, Limited. Arsenopyrite (white), quartz and calcite (black and gray). $\times 50$.

FIG. 2. Skeletal crystals of arsenopyrite. Hard Rock Gold Mines,

During a late period of movement, the quartz-tourmaline veins have been locally faulted and slickensides developed.

Table 2. Arsenopyrite occurs as large well-developed crystals with euhedral outlines (Fig. 1) and as skeletal crystals (Fig. 2). Many of these crystals have been broken across (Fig. 3), the fractures being filled with quartz and metallics. Unfractured pyrite conforms to arsenopyrite but is, in part, automorphic against quartz. A considerable overlap between pyrite and quartz is indicated by the fact that much of the pyrite conforms to quartz crystal outlines. In several of the sections a period of shearing is suggested by the parallel alignment of flakes of graphite and the rounding of pyrite masses, and quartz may have been introduced or recrystallized during this shearing. The overlap relationship of pyrrhotite and quartz was seen in some sections where quartz conforms to pyrrhotite outlines. The deposition of pyrrhotite continued past that of sphalerite, resulting in the overlap relationship shown in Table 2. Galena and sphalerite have mutual boundaries in some sections, but for the most part galena conforms to sphalerite and has mutual boundaries with some of the pyrrhotite. Chalcopyrite in places conforms to galena and pyrrhotite, but was elsewhere observed to have mutual boundaries with these

Limited. Arsenopyrite (white and somewhat mottled—the mottled appearance is due to reflection pleochroism), quartz (black), calcite (dark gray). $\times 50$.

FIG. 3. Arsenopyrite lath fractured transversely. Hard Rock Gold Mines, Limited. Arsenopyrite (white—note the matching walls in the fractures), pyrite (light gray), quartz and calcite (dark gray). $\times 50$.

FIG. 4. Automorphic replacement of argillite by pyrite. Bankfield Consolidated Mines Limited. Pyrite (light gray—note the manner in which the “grain” of the rock is transected), non-metallics (black). $\times 50$.

FIG. 5. Euhedron of pyrite fractured and displaced. Tombill Gold Mines Limited. Pyrite (light gray—note the manner in which the larger part has broken the smaller), quartz (black), calcite (dark gray). $\times 50$.

FIG. 6. Galena with euhedral gold. Magnet Consolidated Mines Limited. Galena (white), gold (grayish, scratched—note the euhedral grains, stippled, surrounded by galena in the middle of the figure), quartz (dark gray). $\times 110$.

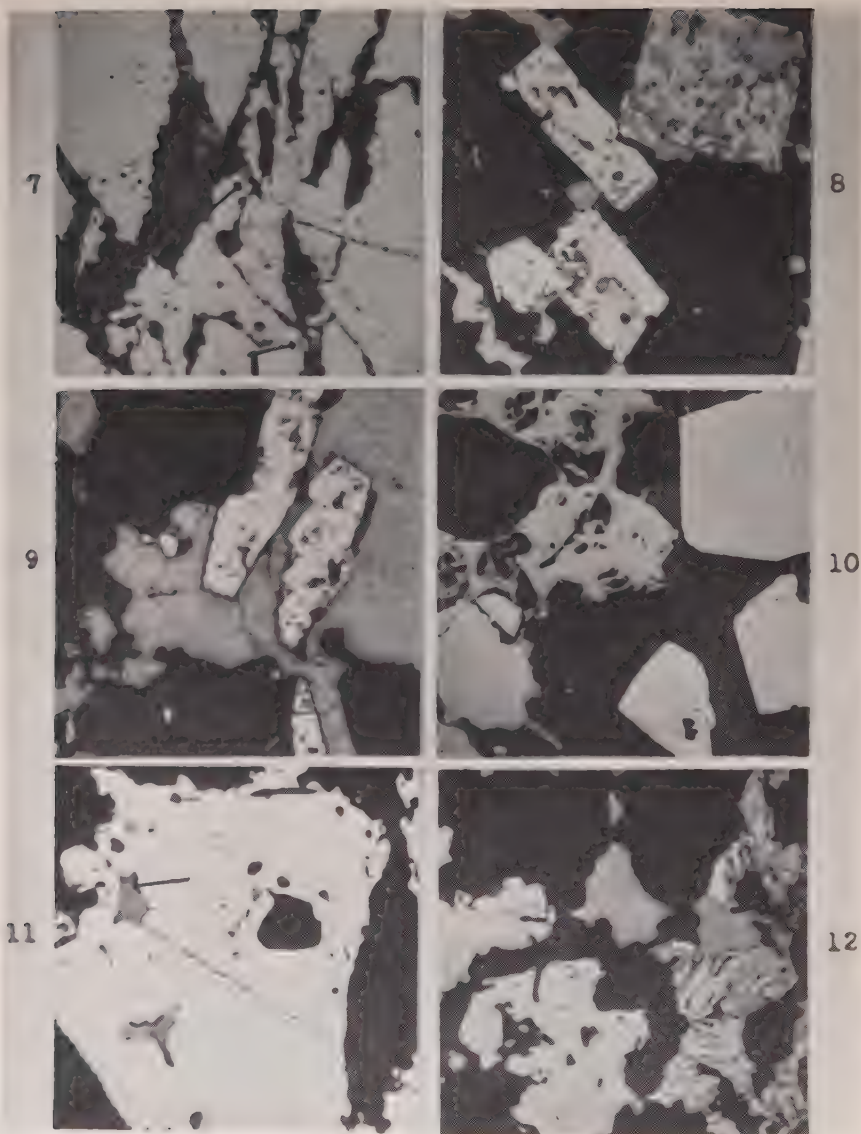


FIG. 7. Gold with quartz in fractured arsenopyrite. Hard Rock Gold Mines, Limited. Arsenopyrite (white), quartz (dark gray), magnetite (light gray), gold (indicated by arrows). $\times 110$.

FIG. 8. Gold associated with pyrite and quartz. Bankfield Consolidated

two minerals. The gray mineral identified as ilmenite(?) is later than chalcopyrite, in some places replacing it, in others conforming to the outlines of the minerals which precede it in the table. Minute crystals of a mineral identified as leucopyrite are associated with pyrite and conform to its outlines. Although not observed in association with ilmenite, the position noted for it in the table is probably correct.

During the second period of fracturing, which followed the deposition of leucopyrite, all the former minerals were broken transversely. Minute euhedra of arsenopyrite are embedded in the quartz-calcite filling of the interstices. Calcite conforms to the later arsenopyrite but preserves its outlines against quartz with only a slight overlap in the sequence. A second age of pyrite occurs as small grains which are in overlap relationship with quartz. Most of the pyrite conforms to quartz, but some is automorphic against it. Pyrrhotite was found alternating with pyrite in a veinlet in one of the hand specimens. The position of gold is difficult to ascertain definitely (Fig. 7). It was probably brought in along with these later solutions and deposited last. The late calcite shown in the table represents calcite, possibly of supergene origin, which has crystallized in vugs.

Mines Limited. Gold (light gray), pyrite (white), quartz (black). $\times 110$.

FIG. 9. Gold associated with arsenopyrite and quartz. Tombill Gold Mines Limited. Gold (light gray), arsenopyrite (white), quartz (black). $\times 110$.

FIG. 10. Pyrite with quartz and chalcopyrite. Tombill Gold Mines Limited. Pyrite (white), quartz (black), chalcopyrite (light gray). $\times 50$.

FIG. 11. Inclusions of chalcopyrite and pyrrhotite in pyrite. Hard Rock Gold Mines, Limited. Pyrite (white), pyrrhotite (dark gray), chalcopyrite (light gray—lath of cubanite indicated by arrow), quartz (black). $\times 110$.

FIG. 12. Intergrowth of pyrrhotite and leucopyrite. Magnet Consolidated Mines Limited. Pyrrhotite (medium gray), leucopyrite (light gray, dendritic mineral), pyrite (white), quartz (black). $\times 110$.

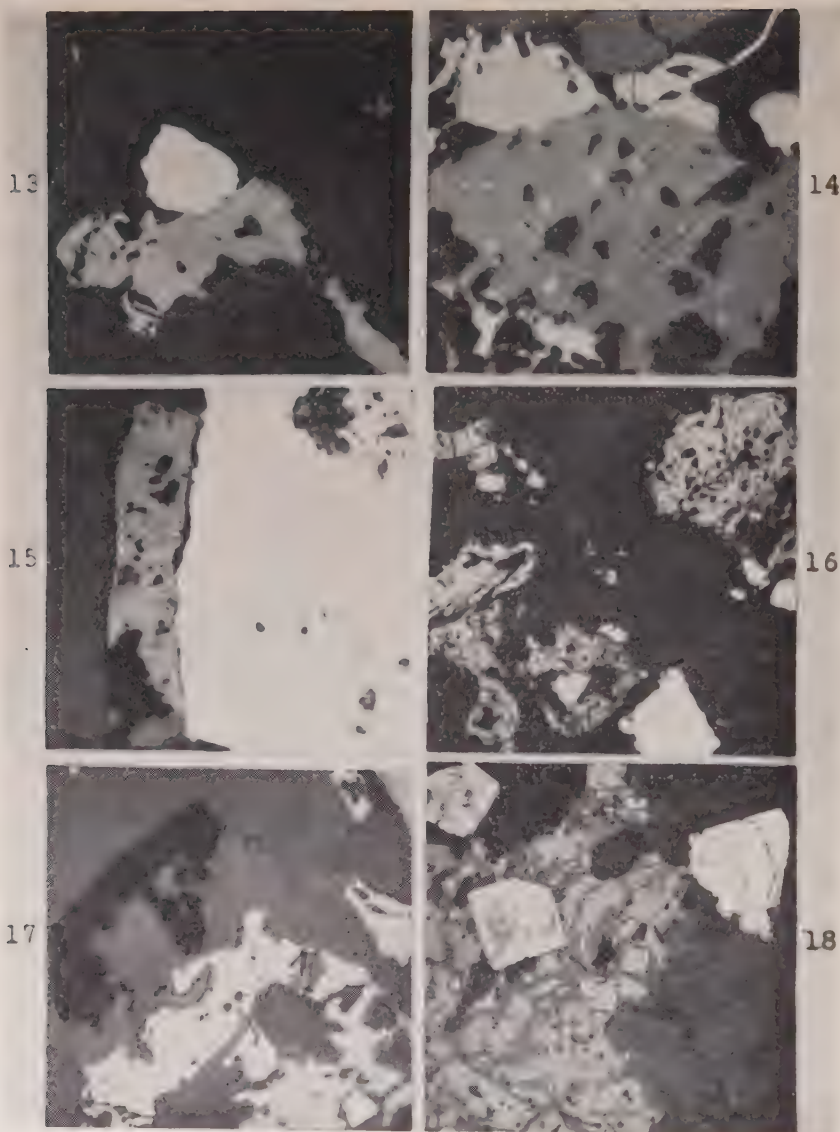


FIG. 13. Pyrite, pyrrhotite, and chalcopyrite. Magnet Consolidated Mines Limited. Pyrite (white), pyrrhotite (medium gray), chalcopyrite (light gray), quartz (black). $\times 110$.

FIG. 14. Chalcopyrite and sphalerite. Tombill Gold Mines Limited.

MacLeod-Cockshutt Gold Mines Limited.

General Geology. The rocks in the MacLeod-Cockshutt group of claims are identical with those in the adjacent Hard Rock group, but the types of rock which outcrop afford a few points of difference. At the western boundary of the group a bed of conglomerate outcrops. At one place it is thirty feet thick and contains pebbles of granite, porphyry, and quartz embedded in a foliated quartzose matrix. Diabase dikes in the MacLeod-Cockshutt property do not outcrop, but occur only as fine-grained black dikes in the underground workings. A third difference is the presence of more iron formation in the MacLeod-Cockshutt than in the Hard Rock claims.

The Orebodies. The geology and structural relations of the ore deposits at MacLeod-Cockshutt have been investigated by H. F. Morrow.⁸ He discussed three distinct types of orebodies at

⁸ Morrow, H. F.: *Geology and Ore Deposits of the MacLeod-Cockshutt Gold Mines, Little Long Lac Area, Ontario.* (Unpublished M.A. thesis, Dept. of Geol., Queen's University, 1940.) Pp. 13-39.

Chalcopyrite (white—smooth contacts and presence as exsolution blebs suggest contemporaneity of chalcopyrite and sphalerite), sphalerite (gray), quartz (black). $\times 120$.

FIG. 15. Hematite between quartz and pyrite in veinlet. MacLeod-Cockshutt Gold Mines Limited. Hematite (light gray band), pyrite (white), quartz (dark gray), magnetite (light gray grains scattered in pyrite). $\times 55$.

FIG. 16. Ilmenite with pyrite and quartz. Bankfield Consolidated Mines Limited. Ilmenite (gray), pyrite (white—contains tiny inclusions of gold), quartz (black). $\times 110$.

FIG. 17. Malachite, limonite, and chalcocite with chalcopyrite, pyrite, and quartz. Bankfield Consolidated Mines Limited. Pyrite (white euhedral grain), quartz (black), chalcopyrite (light gray), chalcocite (lighter gray bands in and around chalcopyrite), limonite (dark gray bands associated with chalcocite), malachite (radiating clusters of needles). $\times 110$.

FIG. 18. Chalcopyrite and pyrite with chalcocite-limonite veinlets. Bankfield Consolidated Mines Limited. Chalcopyrite (light gray), pyrite (white), chalcocite (lighter gray bands in chalcopyrite) limonite (dark gray bands associated with chalcocite), quartz and calcite (dark gray). $\times 55$.

the mine: the South Ore Zone, the North Ore Zone, and the 210 Quartz Vein. Recent developments since the summer of 1940 have indicated the presence of a fourth orebody, to be known as the West Ore Zone.

The South Ore Zone is one of fracturing and shearing, closely following the contact between the albitite porphyry and greywacke. Gold values are limited to the sheared rocks which include the porphyry where the tongues of that rock are narrow. Massive sulphides comprise the major ore minerals; in some places tongues of sulphides have replaced the greywacke along shear and bedding planes.

The North Ore Zone is composed of lenses of sulphides in a band of iron formation. The lenses are short and wide and lie close together along the contorted contacts between the more typical iron formation and greywacke containing a low percentage of iron. In places the structure of the ore shoots is very irregular with finger-like tapering ends. The sulphides have selectively replaced sheared greywacke along the shear planes, rather than the massive iron-rich bands. Many sulphide veinlets transect the shear planes of the greywacke where cross fractures afforded easy access of ore-bearing solutions. The stopping length of the ore zone is about 600 feet, the width averages 12 feet, but varies within much wider limits.

The 210 Quartz Vein is a closely folded saddle that lies entirely within the albite porphyry and contains visible gold. The vein, from which irregular quartz stringers branch, overlies an anticlinal mass of greywacke.

The West Ore Zone, 1,400 feet west of the North Ore Zone, comprises lenses of sulphides in iron formation that has been drag folded, and dips north at 68° . As in the North Ore Zone, the sulphides have selectively replaced the softer sheared portions of the iron formation. Several quartz veins containing free gold were found in the greywacke immediately south of the iron formation. A single specimen, part of a drill core, is composed almost entirely of pyrrhotite, but contains considerable free gold.

Production figures show that, in the year ending September 30, 1941, 240,098 tons of ore were milled for an average recovery of \$9.52.

Mineral Paragenesis (Fig. 15). The mineralogy at the MacLeod-Cockshutt mine is similar to that at Hard Rock. Ten metallic minerals were identified, and three minerals were tentatively identified as tellurides. Pyrite is the most abundant sulphide as arsenopyrite is less common than at Hard Rock. Free gold was found in more than half the polished sections and in some of the hand specimens.

The mineral sequences have been compiled for each of the ore zones in the following tables:

TABLE 3.
210 QUARTZ VEIN.

Quartz	-----
Pyrite	--
Fracturing	xxx
Krennerite (?)	-
Galena	-----
Gold	-----
Coloradoite (?)	?--?
Mineral X	?--?

TABLE 4.
NORTH ORE ZONE.

Arsenopyrite	---
Pyrite	-----
Quartz	-----
Local Fracturing, elsewhere	----- continuity
Quartz	-----
Pyrrhotite	----
Sphalerite	--
Chalcopyrite	----
Leucopyrite	----
Jasper	----
Hematite	----
Fracturing	xxx
Quartz	-----
Calcite	-----
Gold	----
Pyrite	----

TABLE 5.
SOUTH ORE ZONE.

Arsenopyrite	---	
Pyrite	-----	
Quartz	-----	
Local Faulting, elsewhere	-----	continuity
Quartz	-----	
Pyrrhotite	-----	
Sphalerite	---	
Chalcopyrite	-----	
Hematite (?)	---	
Ilmenite (?)	---	
Calcite	-----	
Gold	-----	

TABLE 6.
WEST ORE ZONE.

Quartz	-----	
Pyrite	-----	
Pyrrhotite	-----	
Sphalerite	---	
Chalcopyrite	-----	
Leucopyrite	---	
Calcite	-----	
Gold	-----	

Table 3. The specimens from this high-grade vein contain spectacular amounts of free gold. The sections are composed almost entirely of gold, galena, and quartz with very minor amounts of pyrite and several minerals identified as tellurides.

Quartz was the first mineral to crystallize and in almost all cases is automorphic against pyrite, the second mineral. Pyrite is represented by only a few small grains, which rarely show crystal faces against the quartz. Quartz and pyrite were fractured during a period of movement, and the fractures filled with galena and gold. The walls of the fractures are generally ragged, due to this replacement. The relation of gold and galena to one another indicates they were contemporaneous; as many cases of gold conform to galena as the reverse. A lath-shaped mineral identified as krennerite (?) which was found in the galena is due to prior crystallization or automorphic replacement. Galena and gold are replaced by coloradoite (?) and an undetermined mineral X but the relations of these two minerals to one another are unknown.

Table 4. In all specimens from this zone arsenopyrite occurs as euhedral crystals, some of which are fractured. Crystals and masses of pyrite conform to arsenopyrite, and to a slight extent, to quartz. In general, quartz conforms to pyrite, but there is a little overlap in the relationship. Some sections contain arsenopyrite, pyrite, and quartz which are fractured; in other sections no fracturing of this period is indicated, but the deposition of quartz continued. Pyrrhotite, sphalerite, and chalcopyrite occur in much the same mutual relationship as in the Hard Rock ores, but are somewhat overlapped by quartz, which rarely conforms to these minor sulphides. Leucopyrite occurs as minute prisms and dendrites which conform to and replace those minerals which precede it in the table. Jasper and hematite were not observed in contact with leucopyrite, but it is probable that they are later. Both occur in fractures in fairly massive pyrite (Fig. 15) which contains blebs of the minor sulphides. Jasper was deposited first; hematite conforms to its outlines and is found in the middle part of the fracture fillings. Later fractures are filled with quartz and calcite which are in overlap relationship; most of the calcite conforms to the quartz, but the reverse is not uncommon. Gold was probably brought in by these late solutions. It conforms to calcite and all other minerals.

The late pyrite noted in the table occurs as drusy coatings in fractures in some of the hand specimens.

Table 5. Except for a greater overlap of quartz and pyrite, the sequence of minerals in this zone is the same as that in the North Ore Zone, as far as the end of the minor sulphides mineralization. In one specimen chalcopyrite is the dominant sulphide. Hematite, which is later than pyrrhotite in most places, conforms to chalcopyrite, but there is evidence that it is partially replaced by chalcopyrite in other specimens. A mineral identified as ilmenite conforms to every other mineral except calcite and gold. Calcite conforms to all those minerals which precede it in the table, but presents crystal faces to the minute grains of gold which was apparently the latest mineral.

Table 6. Only one polished section was available; it is noteworthy for the high proportion of pyrrhotite, and lack of arsenopyrite. Quartz was the first mineral to crystallize, closely followed by pyrite. In most cases quartz is automorphic against pyrite, but the reverse is not unusual. Pyrrhotite and sphalerite were deposited together following pyrite. Chalcopyrite overlaps sphalerite and is automorphic against some of the pyrrhotite. Deposition of pyrrhotite probably continued through rather a long period. Leucopyrite is fairly closely related to pyrrhotite, to which it conforms and which in part it replaces. Calcite conforms to all the minerals which precede it in the table, but presents its own crystal outlines against gold. As before, gold is the last mineral to be deposited; it was deposited in open spaces and also has replaced some of the sulphides.

Little Long Lac Gold Mines Limited.

General Geology. The geology and ore deposits of the Little Long Lac mine have been the subject of several papers by E. L. Bruce^{9, 10, 11} and by E. L. Bruce and W. Samuel.¹²

The rocks in the vicinity of the mine are similar to those of the Hard Rock and MacLeod-Cockshutt mines, comprising basic lavas, sediments, dioritic intrusives, and lamprophyric dikes. No albitite porphyries have yet been found near the orebodies at Little Long Lac.

The "Keewatin-type" basic lavas, which dip steeply southward, lie about one-half mile north of the mine shaft. They are not likely to be encountered underground because the veins are almost vertical.

⁹ Bruce, E. L.: Little Long Lac Gold Area. Ont. Dept. Mines, 44, pt. 3: 33-43, 1935.

¹⁰ —: New developments in the Little Long Lac area. Ont. Dept. Mines, 45, pt. 2: 124-125, 1936.

¹¹ —: Structural relations of some gold deposits between Lake Nipigon and Long Lake, Ontario. ECON. GEOL., 34: 362-365, 1939.

¹² Bruce, E. L. and Samuel, W.: Geology of the Little Long Lac Mine. ECON. GEOL., 32: 318-334, 1937.

The "Timiskaming-type" sediments consist of arkoses, greywackes, iron formation, and conglomerate, all of which are lenticular, partly a relict primary structure, and partly a result of folding. The arkoses contain feldspar in excess of the 25 per cent requisite to the name, but quartz is also abundant. The rock is easily distinguished by its granular texture and gray color on fresh fracture surfaces. Both underlying and overlying the arkose are beds of greywacke, finer grained and darker in color than the arkose. In general, the greywacke is massive and contains considerable chlorite, but parts of the overlying layer are somewhat slaty. The iron formation bears the same relation to the greywacke as at Hard Rock and MacLeod-Cockshutt, all gradations being noted between greywacke with hematite and magnetite lenses and the more characteristic banded iron formation. This rock forms two discontinuous bands in the lower part of the sedimentary series. Conglomerate does not outcrop near the mine, but some beds have been encountered underground.

A mass of diorite outcrops about 600 feet south of the ore zone. Underground developments have shown a narrow lamprophyric dike altered to calcite. Outcropping a little more than a mile west of the mine is a narrow diabase dike, trending north-south.

The major synclinal structure of the area of which Little Long Lac is a part is complicated by a large drag fold. The beds, which normally strike almost east-west, are dragged northward about 3,000 feet and then resume their original strike. Shear zones developed in the arkose after the folding strike east-west or just north of east, parallel to the slightly curved axial plane of the drag fold. Measurements show that there is a westward plunge of about 50° to the minor structure. During the folding period the iron formation underwent considerable thickening and thinning and developed intricate plications. At the same time the greywacke developed a rather uniform schistosity, whereas the arkose yielded with the formation of the shear zones.

The Orebodies. The orebodies are confined to shear zones in the arkose beds. The main lode, which strikes nearly east-west and dips steeply to the south, lies about 80 feet south of the axial

plane of the fold. In general, a single lode may be considered to be composed of two quartz veins 3 to 4 inches wide, separated by a sheared zone 40 to 50 inches wide containing numerous veinlets and stringers of quartz. The quartz veins are extremely variable in thickness, but remarkably continuous in length. Some veinlets only a fraction of an inch wide have been traced several feet. Although the veinlets ultimately pinch out, it has been found that others begin along parallel shear planes where the first veinlets end, thus maintaining a fairly constant proportion of quartz.

There are two main zones about fifty feet apart. Linking the two zones are veins which branch off from one main zone and join the other in a reverse curve. These veins plunge eastward in a direction almost perpendicular to that of the drag fold and may represent the original bedding. From the 11th to the 16th levels, the main vein is displaced southward by faulting a distance of about 150 feet.

In the typical lode described above, each of the two quartz veins may assay as high as 20 oz. of gold, but the average is 3 to 5 oz.; the intermediate zone, carrying sulphides, averages about 0.15 oz. It has proved economical to mine out the entire width which then averages about 0.5 oz. gold per ton. The main lode is 800 to 1,200 feet in length and has been developed to 2,200 feet with sixteen levels. During 1941, an internal shaft was sunk from the 16th level in order to open up four new levels. Lateral development is progressing and the vein has been reached on the 17th level. Production figures for 1941 show tonnage milled as 118,332 for a recovery of \$13.82 per ton. Ore reserves at the end of 1941 were estimated at 440,000 tons averaging \$15.67 per ton in gold.

Mineral Paragenesis. In the examination of polished sections from this mine, nine metallic minerals were identified and a tenth tentatively identified. Arsenopyrite and pyrite are again the most abundant sulphides, occurring in about equal proportions. Free gold was observed in about half the sections examined; it was also observed in many of the hand specimens.

ponderance of euhedral over anhedral grains. Whether the grains are diamond or lath-shaped in outline depends upon their orientation in the polished section. The overlap relationship of pyrite and arsenopyrite is suggested in a few places where pyrite is automorphic against arsenopyrite. In some specimens, the arsenopyrite and pyrite are fractured, the cracks being filled and their walls partially replaced by metallic and nonmetallic minerals. In other specimens, no period of fracturing is apparent and quartz was deposited in overlap relationship with pyrite. Quartz always conforms to the crystal outlines of arsenopyrite, or replaces it, and with the exception noted above, is later than pyrite.

The position of the mineral temporarily identified as ilmenite is not very certain. It is probably contemporaneous with the last of the early quartz. Pyrrhotite, sphalerite, and chalcopyrite occur in very much the same relationship to one another as in the Hard Rock ores. They are all later than quartz, and occur as grains and blebs in the gangue, as well as in the major sulphides. Chalcopyrite was seen in several sections filling fractures in pyrite and arsenopyrite, and slightly replacing these minerals. Galena was found in a few specimens where it was automorphic against some chalcopyrite and sphalerite. Mutual boundaries between galena and these two minerals in other places suggest overlap. While leucopyrite was not observed in contact with chalcopyrite, it is later than pyrrhotite, which it sometimes replaces. The major and minor sulphides are automorphic against, or sometimes replaced by, bournonite, but no contacts of leucopyrite and bournonite were seen. Gray copper occurs as small blebs and grains which have mutual boundaries with some of the bournonite. It also occurs as replacement and space-filling blebs in the major sulphides. The mineral identified as ankerite conforms to the outlines of all the minerals which precede it in the table; a few replacement contacts were also observed. Although it is generally automorphic against gold, there were several places where it conformed to the gold outlines, indicating overlap of the two minerals. A second period of fracturing is suggested by the fractures in the quartz and ankerite of the sections. Fractured gold was not observed, probably be-

cause of the small size of the gold grains. The fractures were filled with a quartz-calcite mixture in which quartz crystallized first. The presence of pyrite crystals on the crystals of calcite in one of the hand specimens indicates the late pyrite shown in the table. A specimen of Little Long Lac ore recently sent to the writer contains the mineral scheelite. It was not possible to determine its age relations with all the other minerals, but the fact that it occurs in quartz veins and is cut by later quartz veinlets indicates that it is older than the later quartz. Information supplied by W. Samuel states that the mineral occurs as bunches and blebs in the main vein and in 409 vein. It also occurs as a veining mineral in the rock adjacent to the quartz veins. In 409 vein scheelite averages about three or four pounds per ton; the general average for the two occurrences is somewhat lower, about two pounds per ton.

Magnet Consolidated Mines Limited.

General Geology. The rocks in the vicinity of the mine comprise sediments, intrusive porphyries, and diabase. There are no outcrops in the immediate vicinity; bedrock is covered by a heavy overburden about fifty feet in depth.

The sediments consist of greywacke, conglomerate, and iron formation. The shaft was sunk in a wide band of greywacke. About 100 feet south of the shaft, the greywacke becomes fine grained and then makes a sharp contact with a black slaty rock containing small relatively sparse pebbles which are all highly carbonatized. This conglomerate, like other slaty horizons, is greatly thickened near the axes of minor folds and varies from 30 to 150 feet in thickness. To its south is a band of sericitic quartzite, probably a sericitized relatively coarse band of greywacke. This band is about 100 feet wide and is succeeded on the south by more greywacke. About 400 feet north of the shaft, a pinching and swelling band of contorted iron formation is indicated by diamond drill intersections and dip-needle surveys. A very minor discontinuous band of iron formation strikes slightly to the right of the vein. It crosses the vein at about the center of the ore zone, which is characteristically heavier in sulphides but leaner at the intersection.

About one-third of a mile northwest of the shaft is a body of porphyry which is probably the same as that on the Bankfield property. It should, therefore, be more correctly termed albitite porphyry. A few hundred feet north of this is a mass of diorite or dioritic porphyry. Recent developments have disclosed the presence of a mass of diorite in the shaft below the 1080-foot level. Several narrow but apparently persistent diorite dikes occur to the north of the vein on the 2nd level and a relatively small dike-like mass of porphyry has been indicated by drilling at about 300 yards northwest of the shaft. A diabase dike about 12 feet wide cuts across the vein almost at right angles, dipping steeply to the west. Nine hundred feet east of the shaft there are several north trending diabase dikes. One of these dikes, about 60 feet wide, may possibly mark a fault which has displaced the east continuation of the band of arkose about 170 feet south. This displacement, however, may be due to folding.

The Orebodies. The ore at Magnet Consolidated occurs in two parallel quartz veins which are bordered by narrow zones of sericitization. Intense sericitization colors the rock greenish buff for an inch or less from the quartz beyond which, for a few inches or more, the rock is usually perceptibly lighter colored than is the normal greywacke. In some instances a narrow zone of heavy sulphides continues along the strike beyond where the quartz pinches out. Although of good grade, this material is usually too narrow to mine. There are no indications of shearing or faulting in the country rock along the strike of these zones. The width of the veins in the upper levels of the mine averages about three feet, and their trend is $N75^{\circ} W$ with a dip of about 80° to the south. In the lower levels, the veins average twelve to eighteen inches but the ore shoot is considerably longer than in the higher levels. The dip of the veins here varies from steeply south to steeply north. The veins are developed in medium grained greywacke which has been dragged into a well-developed fold plunging at about 45° to the west. The orebodies rake to the west at about the same angle.

The average ore on the lower levels in the mine contains a high proportion of arsenopyrite. This ore is quite distinct from the

quartz with gold and galena—high grade material—which is particularly abundant in small structures resembling folds in the veins. These structures, according to P. C. Benedict¹⁵ occur in places where the greywacke shows no minor folding. One of the best developed of these plunges east at about 45°, a direction just opposite that of the drag folding. Benedict believes these structures to be “due to the quartz locally following the tension element of the shear pattern for a very few feet.”

The main ore shoot has been developed down to the 1080-foot level, where it is 850 feet in length. Drifting on the 1380- and the 1730-foot levels has disclosed continuation of the orebodies. During 1941, a short shoot of marginal ore was developed in a small vein lying about 600 feet north of the main ore shoot. Production figures for 1941 show 47,731 tons mined. The average recovery, after sorting, was 0.556 oz. per ton.

Mineral Paragenesis (Figs. 6, 12, 13). The mineralogy of the ores from this mine is not complex. Seven metallic minerals were identified, the chief of which is arsenopyrite. Pyrite is present in somewhat minor amount. Free gold was observed in many of the polished sections and hand specimens. It was present in spectacular amount in one specimen from the drag fold on the 1080-foot level.

The following table has been drawn up to represent the sequence of mineralization:

TABLE 8.
MAGNET CONSOLIDATED.

Arsenopyrite	-----	
Pyrite	----	
Fracturing	xxx	
Quartz	-----	
Pyrrhotite	---	
Chalcopyrite	-----	
Leucopyrite	----	
Calcite	-----	
Galena	----	
Gold	----	
Fracturing		xxx
Quartz		---
Calcite		---

Discussion of the Table. Arsenopyrite, as in many of the other mines, was the first mineral to crystallize. The characteristic

¹⁵ Benedict, P. C.: Personal communication.

euohedral outlines are supplanted in some sections by ragged borders due to replacement of arsenopyrite by later minerals. Pyrite usually conforms to arsenopyrite, but one specimen was examined in which pyrite was, in part, the earlier of the two. Since this relationship was observed in only one section, it is indicated by only a slight overlap in the table. In most of the sections, arsenopyrite and pyrite have been fractured, the fractures being filled with metallic or nonmetallic minerals. In other sections there is no evidence of this fracturing and quartz was deposited directly after the pyrite. In all cases quartz is definitely later than the pyrite and conforms to, or replaces, both pyrite and arsenopyrite. Pyrrhotite conforms to the major sulphides and to quartz. It occurs as replacement and space-filling blebs in the major sulphides and in some sections fills cracks. Chalcopyrite occurs in overlap relationship with pyrrhotite; in most places it conforms to pyrrhotite (Fig. 13), but their presence in segmented veinlets in fractured arsenopyrite suggests they are contemporaneous. In a few instances the contacts were such as to suggest that chalcopyrite was the first to crystallize.

Leucopyrite (Fig. 12) was observed in contact with pyrite, pyrrhotite and arsenopyrite. It is distinctly later than pyrrhotite and is probably later than chalcopyrite, although the contact was not observed. Calcite conforms to the tiny prisms and dendrites of leucopyrite. Crystal faces of chalcopyrite and pyrrhotite against calcite also were observed. Galena and gold are essentially contemporaneous (Fig. 6), an equal number of crystal faces of each against the other being found in the sections. Their contacts, if not those of crystal faces, are entire and rounded, rather than ragged replacement contacts. The presence of gold along cleavage planes in calcite in one hand specimen, and the conformity of both galena and gold to calcite in the polished sections indicate their respective ages. One of the hand specimens shows a veinlet of quartz and calcite cutting across the other minerals. It is a fracture filling because the opposite walls match perfectly. Its segmented character indicates quartz and calcite are contemporaneous.

Bankfield Consolidated Mines Limited.

General Geology. The geology and ore deposits of the Bankfield mine have been the subject of papers by A. W. Johnson¹⁶ and E. L. Bruce.^{17, 18, 19}

The rocks in the vicinity of this mine, continuous with those at Tombill, comprise sediments, albitite porphyry, and diorite. The sediments include greywacke, slaty greywacke, conglomerate, and iron formation, of which the greywackes and argillite-like greywackes are the most important. The beds strike almost east-west dipping steeply to the south, but have been fractured and sheared by later deformation. Some of the coarser greywacke has been silicified by solutions from the feldspar porphyry masses.

The sediments are intruded by masses of diorite and albitite porphyry. Diorite occurs as dikes and irregular masses. Some of the more regular masses may actually represent recrystallized volcanics interbedded with the sediments. The albitite porphyry occurs in dikes and elongated lenticular masses striking east-west and dipping steeply to the south. These porphyry masses have been somewhat fractured by the movements which sheared the sediments.

The Orebodies. The original work was done on the North zone which contained some gold but no commercial ore. The entire production of the mine has come from the South zone.

The South zone is continuous with the Tombill orebody, consisting, therefore, of a sheared and fractured zone at the contact of albitite porphyry, greywackes, and lean iron formation. Mineralization is fairly heavy, gold values and sulphides being disseminated in irregular lenses in the sheared rock and in the quartz-filled fractures. One section of the South zone strikes east-west and dips south at about 75° over a length of 275 feet up to the

¹⁶ Johnson, A. W.: *Geology and Ore Deposits of the Bankfield Gold Mine.* (Unpublished M.Sc. thesis, Dept. of Geol. Queen's University, 1935.)

¹⁷ Bruce, E. L.: *Little Long Lac Gold Area.* Op. cit., pp. 46-50.

¹⁸ —: *New developments in the Little Long Lac Gold Area.* Op. cit., pp. 135-140.

¹⁹ —: *Structural Relations of some gold deposits between Lake Nipigon and Long Lake, Ontario.* Op. cit., p. 361.

Discussion of the Table. Arsenopyrite is rather subordinate in quantity to pyrite, but in many cases is the earlier of the two minerals. Skeleton crystals are common in which one or more faces are not developed perfectly. Pyrite presents its own crystal outlines to all other minerals (Fig. 4) sometimes including arsenopyrite. Both pyrite and arsenopyrite are fractured, particularly the larger crystals. Small perfect crystals are considered to be of the same age as the larger but fractured crystals. Quartz was deposited immediately after the period of fracturing; many of the fractures in the major sulphides have been sealed with quartz or minor metallics. Ilmenite (Fig. 16) conforms to quartz, but itself is automorphic against, or replaced by, the later minerals. Pyrrhotite, sphalerite, and chalcopyrite are related to one another in the same way as in most of the other mines, and are later than ilmenite. Gray copper is overlapped by chalcopyrite, but is later than pyrrhotite and sphalerite. It occurs as inclusions in pyrite in one polished section, where it appears to be later than pyrrhotite but contemporaneous with some of the chalcopyrite. Early calcite conforms to chalcopyrite and all the other minerals with the exception of gold. The exact position of gold in the sequence is not definite; it may be earlier than the second fracturing, or it may have been brought in by the solutions which followed that fracturing. One very high grade specimen contains considerable free gold which occurs as blebs and veinlets in quartz and pyrite (Fig. 8). The veinlets are of the replacement type; the blebs are commonly outlined by smooth crystal faces of quartz or pyrite. None of the sections examined shows the second period of fracturing. Many of the hand specimens, however, are cut by veinlets of quartz and calcite in which the calcite is located medially, conforming to the crystal outlines of quartz.

The supergene minerals are interesting in their relationships. Pyrite and chalcopyrite are intricately laced with networks of chalcocite and limonite veinlets showing the abrupt ends characteristic of replacement (Fig. 18). In these ribbon-like veinlets chalcocite lies nearest the primary mineral. Limonite forms

a narrow strip down the middle of the veinlets; it is later than the chalcocite. Malachite (Fig. 17) was found in only one part, where it forms a cluster of fine green needles radiating outward from the limonite rims of a chalcopyrite grain. Close to this group is another cluster of brown needles of limonite or goethite. The similarity of occurrence of the two clusters suggests an overlap in the relationship between the two minerals. Calcite has filled the interstices between the needles of malachite; their relative ages are thus indicated.

Tombill Gold Mines Limited.

General Geology. The rocks in the vicinity of the Tombill mine are covered by about ninety feet of glacial drift. Those encountered in the underground workings are the same as those in the adjoining Bankfield mine.

Greywacke occurs in parallel bands and lenses striking N72° W, and dipping steeply to the south. Several varieties have been mapped, including chloritic and arkosic greywackes. The sediments have been intruded by diorite and by quartz-feldspar porphyry. The latter is a continuation of the Bankfield rocks identified by E. L. Bruce²² as an albitite porphyry. It occurs as elongated lenticular masses in the diorite south of the vein and in the greywacke to the north. Where the intrusive character of the diorite is in doubt, it is possible that the rock is actually recrystallized volcanic material. The Tombill shaft is sunk in arkosic greywacke 75 feet north of the vein.

The Orebodies. There are two ore zones at Tombill, the North and the South. The South zone is a continuation of the main Bankfield ore zone, silicified at the contact of the diorite and the sediments and probably represents silicified greywacke or arkosic greywacke. This is the only zone in production. Underground developments over a length of 2,000 feet have disclosed six blocks of ore. The steep southerly dip carries the vein into the Bank-

²² Bruce, E. L.: New developments in the Little Long Lac Area. Op. cit., pp. 137-138.

field property to the south below the 600-foot level. The annual report dated March 1, 1941, disclosed that the South ore zone has been fully prospected and that no further ore is expected. A fairly wide siliceous zone 300 feet north of the shaft is lightly mineralized but has yielded no ore.

The North ore zone lies about 2,000 feet north of the South, and contains a twelve-inch band of iron formation interbedded with greywacke, which is irregularly folded and carries low values. The possible ore of the North zone is associated with a narrow silicified quartz feldspar dike carrying some visible gold and scheelite but not in commercial quantities. A crosscut extending northerly from the second level station was driven more than 2,000 feet, but the results of the exploration work and drilling, including 430 feet of drifting, disclosed no ore under the present conditions. Some of the material was run through the mill, but proved to be too low grade.

The orebodies are generally lenticular in shape and their underground structure is not complex. Numerous minor faults have been encountered in the South ore zone. Most of these faults trend northwest and dip southwest. The most important fault dips about 42° to the southwest, the throw along it amounting to about 40 feet. The west end of the vein has been displaced to the north relative to the eastern extension.

During 1941, a total of 46,956 tons of ore was milled for a recovery of \$10.81 per ton. Reserves at the end of 1941 were expected to be exhausted about September, 1942.

The property of Elmos Gold Mines Limited, lying three miles to the east adjacent to Little Long Lac and MacLeod-Cockshutt, has been acquired and is being dewatered. Ore from this property will be milled when the Tombill orebodies are exhausted.

Mineral Paragenesis (Figs. 5, 9, 10, 14). Polished sections permitted the identification of seven metallic minerals. Free gold was observed in almost all the specimens, two of the hand specimens being very high grade. One specimen contains a very high proportion of chalcopyrite, but pyrite is the conspicuous sulphide in the other sections.

show tiny euhedra of pyrite in some of these veinlets; it is earlier than the quartz or calcite. Gold was apparently introduced after the second fracturing. It occurs as fracture fillings in the early quartz and is later than the chalcopyrite with which it is sometimes associated. In the high grade sections, gold occurs with pyrite and arsenopyrite, sometimes replacing them, in other places surrounding euhedra of the sulphides with no apparent action on them (Fig. 9).

Jellicoe Mines (1939) Limited.

General Geology. The ore deposits at the Jellicoe mine are associated with sediments and intrusive porphyries. Bedrock in the vicinity of the mine is covered with a heavy overburden of glacial drift about 50 feet thick.

The sediments comprise greywackes grading into "arkoses,"²³ and slaty greywackes, some of which carry considerable chlorite. The shaft is located in a broad belt of chloritic greywacke striking just north of west. A 400 foot band of "arkose" which lies 50 feet south of the shaft contains the Main Zone orebodies. About 900 feet north of the shaft is a narrow band of iron formation; a second band of iron formation about half a mile south of the shaft is believed to be a different band.

Just north of the shaft a narrow band of rock, which parallels the trend of the greywacke, has been identified as a diorite sill. The difficulty of distinguishing between intrusive diorite and recrystallized interbedded volcanic material has been noted elsewhere. It is possible that the so-called diorite is such an interbedded volcanic rock.

About 700 feet north of the shaft, a band of rock trends just north of west; it is known at the mine as the "Quartz-feldspar Marker." A similar rock type on the adjacent Tombill property is called quartz-feldspar porphyry. Specimens of these rocks were found to be very similar to the albite porphyry at the Bank-

²³ The term "arkose" as used at this mine is applied to a light-colored rock which may actually be an altered and bleached greywacke.

field mine. The "Quartz-feldspar Marker" is an almost vertical dike cutting across the greywacke at a small angle.

An irregular mass of porphyry associated with conglomerate and chloritic greywacke extends into the property about one mile south of the Jellicoe shaft.

The Orebodies. The Main Zone orebodies are confined to vein quartz and silicified and brecciated zones in the band of arkose just south of the shaft. This band dips to the southwest at 75° to 80° along its northwest strike. Two sections, the eastern and western, of the Main Zone have been developed.

The arkose of the Eastern section is partially silicified and differs from the ore shoots only in its lesser degree of silicification. Free gold was observed only where there is almost 100 per cent quartz. The main structure, as determined by G. C. McCartney,²⁴ Consulting Geologist for the mine, is in the form of a flat "S"; this "S" appears both in plan and in section. The ore of the first level main break forms the body of the "S." On the second level small, flatly westward pitching veins appear as large drags when viewed in plan. A feature of these veins is the variation in the development of vein quartz; in some places, general zones of silicification take the place of vein quartz. All veins and ore occurrences appear to follow crush or fault zones in the arkose. The tailing out ore zone is displaced by a fault about 200 feet west of the shaft. This fault strikes just east of north and dips steeply to the southwest. Beds on the west of the fault are displaced northward about 200 feet relative to the same beds on the east of the fault.

The so-called Western section of the Main Zone was thoroughly diamond drilled from the surface. During the first seven months of 1940 a 2,000 foot drift was run on the 500-foot level from the Eastern section. Further drilling from this location failed to prove anything approaching an economic deposit. Operations by the present company were discontinued permanently on this property in August, 1940.

A total of almost 14,000 tons of ore from the Eastern section

²⁴ McCartney, G. C.: Private report to the directors.

was treated at the Magnet and Bankfield mills. The grade averaged almost 0.4 oz of gold per ton.

Mineral Paragenesis. The mineralogy at the Jellicoe mine is not complicated. Eight metallic minerals were identified. Arsenopyrite is more abundant than pyrite. Free gold was observed in more than half the polished sections, and in a few of the hand specimens.

The sections and hand specimens indicate only one, a rather late, period of fracturing. The composite table illustrating the mineral sequence is as follows:

TABLE 11.

JELlicoe.

Arsenopyrite -----
 Pyrite -----
 Quartz -----
 Pyrrhotite -----
 Sphalerite -----
 Chalcopyrite -----
 Ilmenite -----
 Stibnite -----
 Fracturing -----
 Quartz -----
 Calcite -----
 Gold -----
 Pyrite (drusy) -----

contact with ilmenite, but the character of its contact with chalcopryite indicates that it is the later of the two.

The evidence for a period of fracturing was observed in a single section where a barren quartz-calcite veinlet cuts the sulphides and quartz. Similar veinlets were seen in several hand specimens. In these veinlets quartz crystallized prior to calcite. In some sections, calcite was deposited from fracture-filling solutions which penetrated beyond the fissures. Gold was carried in by these solutions and in several places conforms to the calcite. In unfractured sections, the gold fills spaces between the earlier minerals. Drusy pyrite was observed in some of the hand specimens, where it was deposited in fractures on the second generation of quartz.

SUMMARY AND CONCLUSIONS.

General Paragenesis.

In the early days of development in the Little Long Lac area, Ellis Thomson ²⁵ examined a collection of specimens. As a result of his study, Thomson outlined a general order of mineral deposition as follows :

1. Quartz, pyrite, arsenopyrite, magnetite.
2. Quartz, pyrite, arsenopyrite, pyrrhotite, chalcopryite, sphalerite, carbonate.
3. Carbonate, pyrite, berthierite, sphalerite.
4. Galena, gold, tetrahedrite.
5. Limonite.

In the course of the present work, the writer found no magnetite which showed evidence of being introduced with the mineralizing solutions. Considerable magnetite was found in the iron formation ores from Hard Rock and MacLeod-Cockshutt, but it is not related to the sulphides which have replaced parts of the iron formation. Other differences from the earlier work are apparent in the table which follows. This table represents a generalization

²⁵ Thomson : Op. cit., pp. 38-41.

one or all three minerals were fractured (Figs. 3, 5, 7). In some cases, this early period of fracturing is lacking.

In almost every mine, pyrrhotite, sphalerite and chalcopyrite occur as blebs and veinlets in the major sulphides and quartz (Fig. 11). Their order of deposition and mutual relationships are the same in each place, even if one of the three is missing. Chalcopyrite and pyrrhotite are abundant locally (Figs. 10, 13), but sphalerite never forms a major part of the ores (Fig. 14). The relationships of graphite and ilmenite to each other and to the other minerals are not nearly as constant as those of the above three minerals. Neither graphite nor ilmenite is abundant in any section. Graphite was observed in only two mines; in one it was deposited during movements which followed the deposition of quartz, in the other it is distinctly later than chalcopyrite and probably later than ilmenite. Ilmenite was observed in specimens from seven different orebodies (Fig. 16); in three of these it precedes pyrrhotite, in the other four it is later than chalcopyrite. Galena, also, does not show constant relationships. It was identified in sections from four orebodies; in two of these it occurs with pyrrhotite, sphalerite and chalcopyrite in overlap relationship, in the other two it is later than chalcopyrite and contemporaneous with the early gold (Fig. 6). In the latter cases, galena forms a fairly high proportion of the sections as distinct from its minor development when closely associated with sphalerite.

Stibnite, leucopyrite (Fig. 12) and the sulpho-salts bournonite and gray copper are found locally and in very minor amount. Their respective ages are indicated in the table; everywhere they are later than chalcopyrite and earlier than gold or the later fracturing.

The jasper and hematite noted in the table occur in a section from the North Ore Zone at MacLeod-Cockshutt (Fig. 15). They are included here for the sake of completeness. In that section they are later than leucopyrite but earlier than the late fracturing. A second or late period of fracturing is indicated in specimens from almost every orebody. Preceding this fracturing,

but later than the sulpho-salts in many of the sections, is an early carbonate, generally calcite. At Little Long Lac, however, ankerite occurs. The carbonate may be followed by gold or by galena and gold. This early gold was observed in specimens from several of the mines. Where the second fracturing is lacking, gold is associated with the carbonate. The euhedral lath-shaped crystal embedded in galena, as observed in one section from the 210 Quartz Vein at MacLeod-Cockshutt, is possibly the telluride, krennerite. It is possible that it may be an automorphic replacement of the galena, but it is considered to be a prior crystallization. Other telluride-like minerals from the same location are apparently later than the gold and galena which they have partially replaced.

The fractures which have resulted from the late fracturing are filled with quartz and calcite. In these veinlets, the quartz began to crystallize first, but it is overlapped considerably by calcite. The veinlets commonly carry other minerals in addition to quartz and calcite. In sections from two orebodies pyrite was earlier than the late quartz; in another section it is later, overlapping the calcite deposition. Tourmaline in one section followed the pyrite but preceded quartz as shown in the table. Hand specimens from one orebody were cut by veinlets containing pyrrhotite with quartz, calcite and pyrite. The pyrrhotite is later than the calcite, but is contemporaneous with the later part of the pyrite. Gold is associated with many of these veinlets where it was deposited late in the sequence. Early and late gold were not found together in any one section. It is possible that both ages may be represented in some of the high grade specimens (Figs. 6, 7, 8, 9) but no criteria for distinguishing between them were found. It has been suggested that gold very closely associated with pyrite may have been in solid solution. Spectrographic investigations recently reported by P. E. Auger²⁶ indicate, however, that gold takes no part in the structure of pyrite crystals as solid solution, but rather occurs

²⁶ Auger, P. E.: Zoning and district variations of the minor elements in pyrite of Canadian gold deposits. *ECON GEOL.*, 36: 412, 1941.

as later replacements or fracture fillings. These findings are quite in accord with the observations made during the present study.

Drusy coatings of calcite and pyrite were observed in several hand specimens from different parts of the area. They probably represent the last slow percolations of the ore-bearing solutions.

The presence of chalcocite, limonite, malachite (Figs. 17, 18) and supergene calcite completes the table and indicates the action of downward enrichment and oxidation.

It is apparent from Table 12 that the mineralization in the Little Long Lac area is almost entirely hypogene. It has been considered advisable to express the sequence in terms of the radicles present in the mineralizing solutions as well as in terms of the combination of radicles as minerals. The sequence of radicles is presented in Table 13.

TABLE 13.
GENERAL SEQUENCE OF RADICLES.

Radicles	Early	→	Late
BASIC			
Fe			
As			
C			
Ti			
Zn			
Cu			
Pb			
Sb			
Ca			
Au			
Ag and Hg			
ACID			
S			
SiO ₃			
CO ₃			
Te			

Mineralogy.

The minerals which have been identified during the present study are listed in Table 14. Their position in the sequence of mineralization and the genetic conditions under which they were deposited are indicated.

TABLE 14.

	Hypogene			Supergene
	Early	Intermediate	Late	
Elements				
Graphite		R		
Gold		×	×	
Sulphides				
Arsenopyrite	×		R	
Chalcocite				R
Chalcopyrite		×		
Cubanite		R		
Galena		×		
Leucopyrite		×		
Pyrite	×		×	
Pyrrhotite		×	R	
Sphalerite		×		
Stibnite		R		
Sulpho-salts				
Bournonite		R		
Grey Copper		R		
Tellurides				
Coloradoite (?)		R		
Krennerite (?)		R		
Mineral X (?)		R		
Oxides				
Hematite		R		
Ilmenite		×		
Jasper		R		
Limonite				R
Quartz	×		×	
Carbonates				
Ankerite		R		
Calcite		×	×	R
Malachite				R
Tungstate				
Scheelite		R		

R indicates a rare mineral.

Character of the Ore Fluid.

Composition. The ore-bearing solutions contained the following elements: Ag, As, Au, C, Ca, Cu, Fe, Hg, Mg, Pb, Te, Ti, Si, S, Sb, W, Zn, and H₂O. Bruce²⁷ reports in the analysis of mill heads from the Little Long Lac mine, the occurrence of bismuth. No bismuth minerals were observed in the present work.

Wall rock alteration was not studied by the writer. Accord-

²⁷ Bruce, E. L.: Little Long Lac Gold Area. Op. cit., p. 40.

ing to Bruce²⁸ wall rock alteration is not intense except for silicification in some zones, where there has been a considerable development of pyrite. Carbonatization has occurred in some places.

Morrow's²⁹ study at MacLeod-Cockshutt shows considerable alteration of greywacke and porphyry adjacent to the ore zones in the South orebody. He found a gain in K_2O , Al_2O_3 , CaO , MgO , CO_2 , H_2O , FeO , and FeS_2 ; losses were recorded in SiO_2 , Na_2O , and Fe_2O_3 . The gain in potash and alumina represents sericitization; that in lime, magnesia, ferrous oxide, and carbon dioxide represents carbonatization. The increase in FeS_2 represents the dissemination of pyrite through the wall rock. These results indicate that the ore-depositing solutions were alkaline in character, at least so far as the ores of the South ore zone at the MacLeod-Cockshutt mine are concerned. The answer to the question as to whether the solutions were acid or alkaline at greater depths must await further developments of the area.

Temperature. A method for distinguishing between alpha and beta quartz has been developed by V. B. Meen, who applying it to specimens of tourmalinized vein quartz from the Little Long Lac area, found that three specimens showed low-temperature, and three showed high-temperature, characteristics.³⁰ A specimen of quartz with tourmaline and gold, from the same region, showed high-temperature characteristics. Lindgren³¹ has expressed the opinion that, in mesothermal deposits, there are only rare exceptions from the sequence, pyrite preceding arsenopyrite. Bandy³² has recently developed a "normal sequence" theory. In his general paragenesis of hypothermal deposits, arsenopyrite crystallizes prior to pyrite.

²⁸ Ibid., p. 31.

²⁹ Morrow, H. F.: Op. cit., pp. 27-31.

³⁰ Meen, V. B.: The temperature of formation of quartz and some associated minerals. Toronto Univ. Studies, Geol. Ser., 38: 62, 1935.

³¹ Lindgren, Waldemar: Mineral Deposits. 4th ed. rev. McGraw-Hill Book Co., Inc., New York. 1933. P. 544.

³² Bandy, M. C.: A theory of mineral sequence in hypogene ore deposits. ECON. GEOL., 38: 556, 1940.

In the present study, the preponderance of the sequence arsenopyrite before pyrite, especially when considered in conjunction with Meen's results, indicates that the ore deposits may be allocated to Lindgren's hypothermal type. The occurrence of tellurides and the presence of galena and stibnite, however, indicate lower temperatures. It is possible, then, that the ore deposits of the Little Long Lac area are most correctly placed in the upper hypothermal, or lower mesothermal, zone.

Relations of the Ores to Intrusives.

The occurrence of dikes and larger masses of intrusive rocks has been discussed in the section on the general geology of the region. There appears to be no relation between the large albitite porphyry pipe and the ores at Hard Rock and MacLeod-Cockshutt. The porphyry is considerably earlier than the ores, as indicated by the presence of ore masses in cracks and fissures in the porphyry. The molten rock had been intruded, solidified, and fractured before the advent of the ore-depositing solutions. In the four westernmost mines in the area, some of the ores have been found in sheared and fractured porphyry and diorite. The possibility that the ores are genetically related to the porphyry must, however, be kept in mind until evidence to the contrary is found. During a long period of rhythmic violent earth movements, small elongate masses might be intruded along major planes of fracture where rapid cooling could take place. Subsequent movements would fracture and shear parts of these masses which might then serve as favorable loci for the deposition of ore minerals from solutions representing a late phase of the original source magma of the porphyries. The same movements that fractured the rock might aid in the circulation of the ore solutions.

A second possible source of solutions is from the granite masses which lie to the north and south of the belt of mines. Gray granite and pegmatite masses occur six to ten miles south, pink granites six to four miles north of the belt. It is possible that the ore solutions are consanguine with one or other of these rock masses.

The synclinal structure of the region suggests little except that, unless the lower part has been removed by igneous material, a considerable thickness must yet be penetrated before the original Laurentian(?) or Keewatin(?) floor is reached. The fact that the ore deposits occur along the same general strike, that is, parallel to the trend of the country, suggests that the syncline is truncated at depth. The planes thus opened provided easy access of ore solutions, especially when controlled either by structure or lithology or a combination of the two. This is in accord with a statement by E. S. Moore⁸³ to the effect that "in the Precambrian areas the gold commonly has been formed from solutions rising upward along limbs of synclines."

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⁸³ Moore, E. S.: Genetic relations of gold deposits and igneous rocks in the Canadian Shield. *ECON. GEOL.*, 35: 134, 1940.

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